A Hundred Years of Water Chlorination

Toward a Second Century of Misgivings?

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After a workout in the gym, a training run or cycle, a game of squash or a mountain hike, the thought of a refreshing drink of cool, clear water is often uppermost in our minds. Adequately quenching that thirst is a vital aspect of maintaining fitness, health and even beauty. But how pure is the water we drink and are the chemicals used to purify it serving paradoxically to contaminate it? Unless we are fortunate enough to live in an unpolluted rural environment collecting our own water (or have affixed some type of water purifier to our tap), the peculiar odour and taste of the liquid in our glass stand as persistent reminders that the water we drink contains chemicals. Generally, the most noticeable of these is chlorine.

We have come to accept the presence of chlorine in our drinking water as one of the necessary, though slightly unpleasant aspects of maintaining community health. Somewhere along the way, most of us have learned that a number of contagious diseases such as typhoid and cholera have been virtually eradicated by filtering and chlorinating our municipal water supplies. The crucial question which many of us never learned to ask, however, is whether chlorinated water represents a health hazard in its own right. In what follows we shall urge that in the light of recent research on the subject, it is clear that water treated with chlorine should be regarded as potentially detrimental to the health of the community.

WHAT IS CHLORINE AND HOW DOES IT WORK?

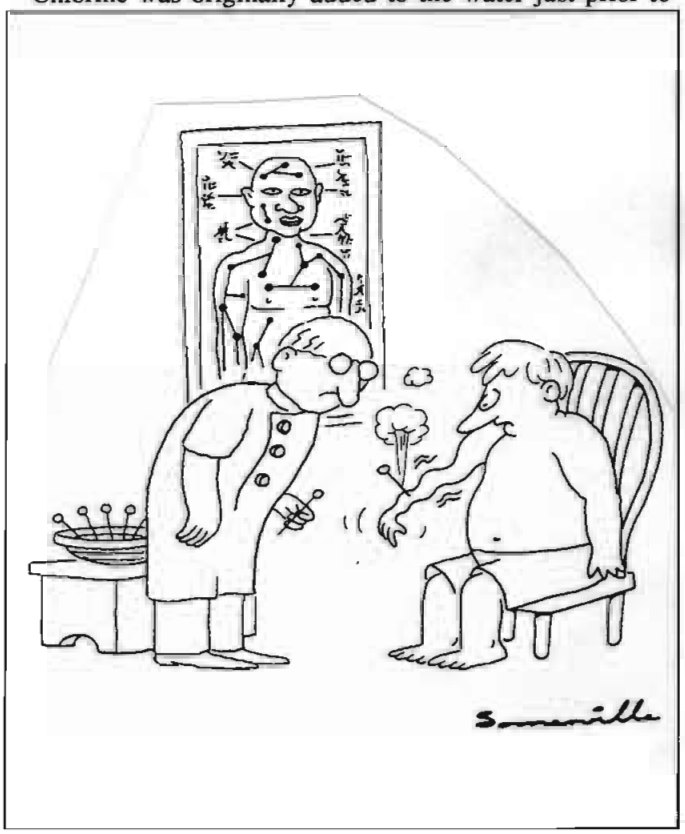
The Australian bicentenary year, 1988, marked the centenary of water chlorination. In 1888 a patent on chlorination of water was granted to Dr. Albert R. Leeds, professor of chemistry at Stevens Institute of Technology, Hobokin, New Jersey. Professor Leeds showed that chlorine could be used as the basis of a method of disinfection to control pathogens responsible for waterborne diseases. In the following year the first chlorination of a public water supply

was initiated at Adrian Michigan, though it was not until 1908 that chlorination was introduced on a large scale at the then huge Boonton Reservoir waterworks in Jersey City, New Jersey. By World War II, the practice of chlorination was widely established in the United States.[1]

The process of water chlorination involves a relatively straightforward chemical process. Chlorine is one of the most reactive elements in nature and is found in a free form only in volcanic gas. Even a small amount of chlorine will dissolve in water, some of it combining with water to form hypochlorous acid and hypochlorite ion. Chlorination of water is achieved by adding chlorine gas directly to the water or by adding the chemicals calcium hypochlorite or sodium hypochlorite. In these latter forms chlorine is known as 'free available chlorine' and has effective germicidal powers because of its ability to combine with or oxidize classes or organic compounds essential to life.

One theory of how chlorine works suggests that there is a physiochemical reaction between chlorine and the structural proteins of the bacterial microbes, thus causing the disintegration of their cell walls. Another popular theory holds that the process of disinfection works by inhibiting a key enzymatic process which oxidizes the glucose of the cell; the bacterial cells die, that is to say, because the chlorine destroys the oxidation process upon which the cells depend.

Chlorine was originally added to the water just prior to filtration, though the more common practice now is to apply chlorine both before and after filtration. The idea is that prechlorination serves to reduce the accumulation in filters of biological material such as algae. Postchlorination is alleged to minimise the number and variety of bacteria which would otherwise enter the distribution system. Chlorine also combines with ammonia and organic nitrogen compounds forming chloroamine. When ammonia is combined with chlorine, a slower acting disinfectant results which has been found to be beneficial in the suppression of iron-fixing or slime-forming types of bacterial growths.



Chlorination is not employed as a substitute for other forms of water treatment; on the contrary the effectiveness of the process to some extent depends upon other treatments such as filtration. Being a very reactive element, chlorine will readily react with many other substances which may be found in water. If a range of these substances are present in the water even in minimal quantities, they may create a chlorine demand which significantly reduces the available chlorine for germicidal purposes. Consequently, chlorination is usually accompanied by filtration to reduce the presence of substances which may create excessive chlorine demand.

Chlorine is notorious for its pungent and disagreeable odour. The human olfactory sense is capable of detecting only a few parts of chlorine per million in the atmosphere, and a concentration of only 50 to 60 parts per million can cause serious illness within one-half hour to one hour. Being a toxic substance, it is capable of causing major congestion of lung tissue and even death if breathed in sufficient quantities.

The odour and taste of chlorinated water may be produced by the presence of excess chlorine or strangely, it may also occur if insufficient chlorine has been added. In the latter case the characteristic odours and taste are produced when chlorine reacts with organic matter such as algae in the water. When stronger chlorine levels are used, the organic matter in the water is destroyed completely, and the result is water which is virtually odour free. From the fact that water odour is minimal it would thus be misleading to conclude that chlorine levels are low and vice versa.

THE POTENTIAL HEALTH RISKS FROM CHLORINATED WATER

It is amazing to think that a very reactive and poisonous chemical could be deliberately added to public drinking water without an extensive study of the possible harmful health effects being carried out beforehand. Yet with chlorination, this appears to have been the case. In 1951, Dr. W.J. Llewellyn wrote to the editor of the *Journal of the American Medical Association:*

What studies have been made to determine the

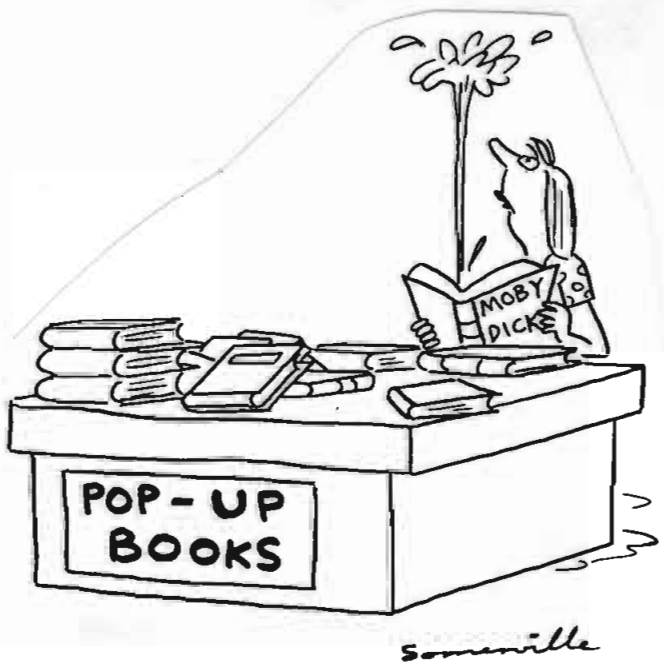
deleterious effects of heavily chlorinated water that is used for drinking purposes? The water supply in our town is chlorinated but not filtered. At times it is possible to smell the chlorine. Could this harm the gastrointestinal or the genitourinary tract?[2]

The editor replied:

A search of the literature did not reveal any organized investigations on the problem of the effect of heavily chlorinated water on the human body. Allergic manifestations of chlorinated water have been reported. Many cases of asthma have been traced to an allergy to chlorinated water. In all these cases the asthma was relieved or disappeared when the patient drank distilled or unchlorinated water.[3]

That same year an awareness of the detrimental health aspects of chlorination was expressed by H.M. Sinclair, Director of the Laboratory for Human Nutrition, Oxford University.

Commenting on heart disease, Sinclair raised what in those times must have seemed an almost incredible accusation. He wrote: "It is possible that one of the greatest public health measures ever introduced - the chlorination of public water supply could assist the [heart] disease".[4] Sinclair himself could hardly have perceived how prophetic the alleged association would be between chlorination and heart disease. In a suggestive study by Ronald Pataki, an astounding correlation of just these factors was discovered in Jersey City, New Jersey, the place - it will be recalled - where the first comprehensive chlorination of municipal water supplies began eighty years ago. Pataki found that the severity of heart disease among people over 50 years of age correlated directly with the quantities of chlorinated tap water they were accustomed to drinking. Interestingly, he also found a statistically significantly correlation which showed that those people over 50 who did <u>not</u> suffer from heart disease standardly drunk mostly non-chlorinated fluids, bottled water, or boiled water (it is known that chlorine can be released as a gas from water which is boiled).[5]



Passwater reports that in South India the water is chlorinated, while in North India, it is not, and consistent with Sinclair's original intuition, the incidence of heart disease in the South is considerably higher than in the North. He also points out that since the drinking water of the northern capital, New Delhi, has been chlorinated, the heart disease rate of that city has sadly begun to climb.[6] In the *National Enquirer* (December 24th, 1974) Dr. Joseph Price of Saginaw General Hospital in Michigan is quoted as saying:

Chlorine is the cause of an unprecedented disease epidemic which includes heart attacks and strokes. Chlorine is an insidious poison Most medical researchers were led to believe it was safe, but we are now learning the hard way that all the time we thought we were preventing epidemics of one disease, we were creating another. Two decades after the start of chlorinating our drinking water in 1904, the present epidemic of heart trouble and cancer began.[7]

In his book titled *Coronaries, Cholesterol, Chlorine*, Price reports a study in which contrast to the control group, chickens reared on chlorinated water <u>all</u> showed evidence of either atherosclerosis of the aorta or obstruction of the circulatory system.[8] Chlorine is further implicated in heart disease by the work of E.P. Benditt, Professor, Department of Pathology at the University of Washington, whose research in 1974 associated plaque formation in the arteries with chlorination. His research suggested that because of mutations in their genetic program caused by mutagenic or even carcinogenic substances in the bloodstream, and other substances released by the arteries as a result of high blood pressure, cells in the arterial wall proliferate to form plaque.[9]

Recent studies by Revis et. al. add further strength to the insidious link between water chlorination and heart disease. They report that they observed "hypercholestorlemia and cardiac hypertrophy in pigeons and rabbits exposed to chlorinated drinking water"[10] and "significant increases in plasma cholesterol and aortic atherosclerosis in pigeons exposed to three commonly used drinking water disinfectants" [chlorine, chlorine dioxide and monochloramine].[11]

In the mid-seventies the issue of the health hazards

associated with chlorinated water was raised from yet another perspective. Awareness of increasing levels of toxic chemicals in water, particularly chlorine containing organic compounds prompted the Environmental Protection Agency (EPA) to undertake a national survey to determine the quality of drinking water throughout the USA. Of particular concern was the formation of chloroform resulting from the use of chlorine for water purification. In 1975 the results of the survey were published,[12] and revealed that drinking water from all the 79 cities tested, contained some amount of the suspected carcinogen, chloroform. Concentrations of chloroform varied from less than 0.1ppm in Strasburg, Pennsylvania, to 311ppm in Miama, Florida. Despite these astonishing results, the EPA representative assured the press that the American people should not react with any sense of panic. Although more than 240,000 sizable drinking water supply systems in the US were deemed likely to be contaminated with one or more of six toxic chemicals, at least two of which are suspected carcinogens, the representatives were warned against any overreaction to the findings of the survey saying that "... the benefits of using chlorine far outweigh the potential health risks from chlorine-derived organic compounds".[13] Despite these assurances, it is clear that the health hazards associated with the presence in drinking water of chlorination induced chemicals are of the utmost seriousness. In 1975, in New Orleans, Louisiana, the tap water was found to contain more organic chlorine compounds than untreated Mississippi River water.[14] The EPA's assurances seemed less convincing when in the following year a major research study reported a statistical correlation between the incidence of cancer among the New Orleans population and their municipal water supplies.[15]

By 1987, a number of studies documented the wide range of toxic substances in drinking water which derive from chlorination.[16] In 1987, a study undertaken by M.K. Smith et.al, demonstrated that a number of the chlorine induced components found in drinking water have in laboratory animals caused reduced fertility and increased failure of early implantation. The birth weight of the pups was reduced significantly and the perinatal survival of the pups was adversely affected by at least two of the halogenated compounds. Short term tests for the carcinogenic effects of several of the chlorinated compounds also proved positive, thereby reinforcing earlier findings which linked chlorination and cancer.[17]

THE CHLORINATION OF WATER AND THE NUTRITIONAL CONNECTION

We have seen that chlorine is a very reactive chemical in water, but what are the effects once this chemical enters our body where it is exposed to a complex and delicately balanced biochemcial organism? The potential health hazards are staggering, but to keep this paper within manageable bounds we shall confine ourselves to a consideration of the impact of chlorination on nutrition.

Chlorine is a powerful oxidising agent with a redox potential in aqueous solutions 1.36 volts. This means that it readily destroys, oxidizes or combines with organic substances such as certain vitamins, enzymes, unsaturated fatty acids and beneficial bacterial.

Let us first consider its impact upon ascorbic acid (Vitamin C). Amongst other important functions this is a vitamin associated with the body's protective action against pollutants. Vitamin C, however, is destroyed by chlorine.

At the same time, if Vitamin C is present in sufficient quantities, it can during the course of time, reduce chlorine to harmless chloride ion, provided the chlorine has not combined with some other organic compound in the meantime. Thus fruit juices, which contain Vitamin C might plausibly offer some protection against the chlorine contained in the water added to reconstitute them.

Another important vitamin affected by chlorine is Vitamin E. It is well known that Vitamin E is an essential factor for maintaining the integrity of the coronary and reproductive systems. Once again, chlorine destroys Vitamin E, and thus drinking large amounts of chlorinated water may destroy Vitamin E in the body. This particular connection may help explain the purported correlations between chlorinated water and heart disease mentioned earlier. Saturated fats in the diet have been associated with heart disease for some time now, and most people are aware of the increasing emphasis in health education to encourage people to replace saturated fats in their diets with unsaturated fats, couple with a reduction of their overall fat intake. Chlorine reacts readily with unsaturated compounds, and whenever chlorinated water and unsaturated fats are mixed the relevant compound may well be toxic. When drinking chlorinated water before or after a meal containing unsaturated fats, or using chlorinated water in food preparations, it would seem that chlorinated compounds could be formed whose carcinogenic effects we considered above. Chlorinated water could thus bring about the very mutagenic processes which lead to cancer.

CHLORINATED WATER AND THE UNKNOWN HAZARDS OF THE SHOWER

There is another side to the chlorine-water story. When we return from a gym workout or a jogging session or a game of squash, not only are we thirsty but we usually shower or bathe to wash away waste products and perspiration. We have been taught that cleanliness and health go together, and indeed they do, when chemical free water is used. When chlorinated water is used, however,

bathing may be much less healthy than we ever supposed.

Gasses are as a rule less soluble in hot water, and when water is heated or boiled, dissolved gasses are released. Boiling water is as we noted earlier a way in which the free chlorine content in water is greatly reduced, the chlorine escaping into the air. When we have a hot shower or run a bath, we can sometimes smell the chlorine released as it escapes from the hot water. In a confined shower recess, however, especially one with poor ventilation, the chlorine escapes from the water as we continue our hot shower and steadily increases in concentration in the air we breath. The olfactory threshold for chlorine is about 3.5ppm (parts per million) so when we can smell chlorine, the concentration is already above this level. The lethal concentration for 10 minute exposure is about 600ppm and we suggest that regularly taking long hot showers with chlorinated water could pose a health risk. Chlorine causes pulmonary oedema, and it would seem likely that regular exposure to chlorine gas even at low levels such as in normal showering may reduce the oxygen transfer capacity of the lungs. This could be a critical factor for athletes and for others prone to heart failure.

Another aspect to be considered is our skin. Our skin is an important protective barrier for our bodies. When we shower with chlorinated water we are essentially exposing our skin to a relatively large volume of a dilute chlorine solution. Some of this chlorine reacts with the oils in the skin to form chlorinated compounds and it is these compounds which may then be absorbed by the body. It seems very likely, considering the strong oxidising power of chlorine, that regular exposure to chlorinated water serves also to promote the ageing processes of the skin, not unlike extended exposure to sunlight. Moreover, chlorine may actually enhance the ageing effects of ultraviolet radiation by reinforcing the process of cell deterioration.

Another skin factor to be considered is the destruction by chlorine of the natural bacteria on our skin. Our skin has an ecology all of its own, which needs to be preserved in order to maintain healthy skin and its associated beauty.

THE EDUCATIONAL GOAL

The complete chlorine-health picture is even larger and more disconcerting than we have intimated in the limited space available. Whenever a toxic substance is deliberately added unreflectively in large quantities to the environment, the overall balance of nature Continued on page 67

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is changed and the chain of reactions produced can be very disruptive, far reaching and often unexpected. We have not, for example, discussed the detrimental impact upon the ozone layer caused by the enormous quantities of chlorine released around the globe.

With education we can begin to discern that nature carries within itself important patterns for the design of our health, and optimum fitness, even for the natural beauty of ourselves and our planet. When all is said, it is apparent that nature did not intend that we despoil it and ourselves by contaminating it with the waste products of the technology we have used to dominate it. After 100 years of chlorination it is surely time to express our misgivings about the prospect of continuing as we are to celebrate its bicentenary.

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